PRODUCTION OPTIMITIZATION IN A HYDRAULIC CYLINDER WORKSHOP

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ABSTRACT

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ABSTRACT

Belautozap is a company located in Belarus that designs and manufactures hydraulic cylinders. Not until a while ago they were struggling after having made some wrong investments where their production took a toll. Now things are brighter and they are recovering and looking for solutions to increase their productivity.

This research work aimed to analyze the current state of production and to implement a method to increase the production volume of hydraulic cylinders. Most of the data used here came from reports, daily logs and from employee interviews. The data was then analyzed to find the bottlenecks in the production line and to start working on solutions to improve productivity.

This project revealed that the main problems in the company were workers who lacked motivation and were taking their tasks too lightly. Other than that, the degree of machine idling time was too high and it was possible to reduce it by rearranging the responsibilities on different people.

At the end of this project two solutions were implemented into Belautozapchast that led to an 18% increase in the production volume.

Keywords Optimization, production, planning, CNC

Pages 20 p.

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1 INTRODUCTION

The aim of this study was to analyze the current situation at work and to implement solutions to improve the hydraulic cylinder production line at Belautozapchast. This chapter aims to introduce the reader to this bachelor’s thesis and to give an introduction to the subject and the company.

1.1 Company background

The work was done at Belautozapchast, which is located in Zhodino Belarus. Belautozapchast is a medium sized company that designs and manufactures hydraulic cylinders. It was founded in 2000 as a hydraulic cylinders maintenance and repair company. A few years later they also started doing hydraulics installation on different machines. In 2011 they moved to their current location in Zhodino and expanded further to start making their own hydraulic cylinders. At this moment they have three segments: maintenance, installation and full cycle manufacturing of hydraulic cylinders.

1.2 Objective

The main objective of this project was to find a solution to how production could be increased at Belatuozapchast while maintaining the same quality. To reach this objective the following goals had to be met:

- To analyze how the operators spent their working day and time spent on different tasks.
- To reduce the time wasted on non-productive activities.
- To find bottlenecks in the production line and to eliminate them.

2 THEORY

2.1 Classification of production system

There are four types of Production systems from which an organisation can choose to use in their production processes. They differ based on volume and variety of production as shown in Figure 1.

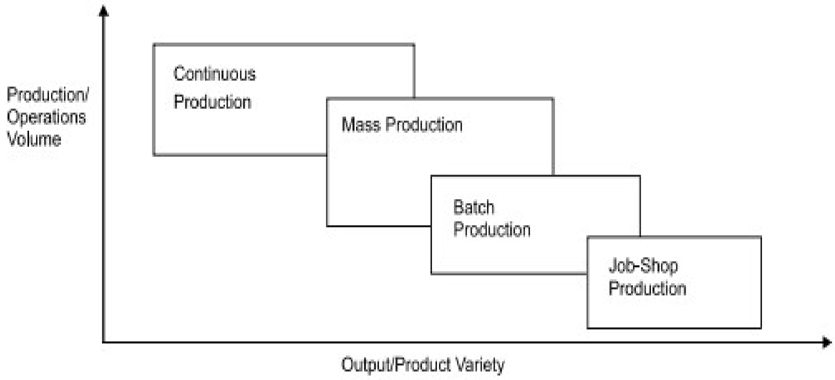

Figure 1. Classification of production systems (Kumar, 2008).

2.1.1 Job-shop production

The main characteristic of Job-shop production is uniqueness over quantity. In such production one or a few products are designed and manufactured as per the customer's specifications within a set time and cost. This leads to low volumes and a high variety of products produced (MBA Knowledge Base, 2012).

Characteristics:

1. High variety and low volume of products.
2. Use of general purpose machines and facilities.
3. Operators have enough skill and experience to make all kinds of unique products.
4. Large inventory of materials, tools, parts.
5. Materials are purchased when orders are received
   Detailed planning is essential for sequencing the requirements of each product, capacities for each work centre and order priorities.

Advantages:

1. General purpose machines and facilities allow variety of products to be produced.
2. Challenging tasks allows operators to increase their work proficiency and gives them learning opportunities.
3. Operators can be utilised to their full potential.
4. Opportunity exists for creative methods and innovative ideas.

Limitations:

1. Frequent set up times lead to increased cost and time of production.
2. Large work-in-progress inventory.
3. Production planning is complicated.
4. Larger space requirements. (Kumar, 2008.)

2.1.2 Batch production

Batch production is defined by American Production and Inventory Control Society (APICS) *"as a form of manufacturing in which the job passes through the functional departments in lots or batches and each lot may have a different routing."* Its main characteristic is manufacturing limited number of products at regular intervals and stocked awaiting sales. (Kumar, 2008.)

Characteristics:

1. Short production runs.
2. Plant and machinery are flexible.
3. Plant and machinery set up is used for the production of item in a batch and change of set up is required for processing the next batch.
4. Manufacturing lead time and cost are lower as compared to job order production.

Advantages

1. Better utilisation of plant and machinery.
2. Promotes functional specialisation.
3. Cost per unit is lower as compared to job order production.
4. Small investments needed for plant and machinery.
5. It is easy to accommodate and realize number of products. Job satisfaction exists for operators.

Limitations

1. Material handling proves to be a challenge due to irregular and longer flows.
2. It is complicated to plan and control production process.
3. Work in process inventory is higher compared to continuous production.
4. Set up costs are higher due to frequent changes in set up.

2.1.3 Mass production

In short, mass production is manufacturing large amounts of standardized products. The machines are arranged in a line or product layout. Product and process standardisation exists and all outputs follow the same path.This system utilizes assembly line techniques to pass partially ready products to workers down the line who each work on an individual step, rather than having a worker work on a whole product from beginning to the end. (Kumar, 2008.)

Characteristics:

1. Product and process sequence are standardised.
2. Machines are specialized which leads to them having high production capacities and output rates.
3. Large production volume.
4. Short production cycle.
5. Low work-in-progress inventory.
6. Steady flow of materials and components.
7. Planning and controlling production is a simple task.
8. It is possible to make material handling fully automatic.

Advantages:

1. High production rate and low cycle and lead times.
2. Higher capacity utilisation due to line balancing.
3. Less skilled operators are needed.
4. Small inventory.
5. Manufacturing cost per unit is low.

Limitations:

1. Breakdown of one machine will stop an entire production line.
2. Any change in the product design with lead to a major change in line layout.
3. Production facilities require high investments.
4. The cycle time is determined by the slowest operation.

2.1.4 Continuous production

Production facilities are made specifically for one product to go full sequence from the first operation to the finished product. The items are made to flow through the sequence of operations through material handling devices such as conveyors, transfer devices, etc. (Kumar, 2008)

Characteristics:

1. Dedicated plant and equipment with zero flexibility.
2. Production runs non-stop.
3. Material handling is fully automated.
4. Process follows a pre-set sequence of operations.
5. High investments in facilities.
6. Planning and scheduling is a routine action.

Advantages:

1. Standardisation of product and process sequence.
2. Higher rate of production with reduced cycle time.
3. Higher capacity utilisation due to line balancing.
4. Manpower is not required for material handling.
5. Person with limited skills can be used on the production line.
6. Unit cost is lower due to high volume of production.

Limitations:

1. There is no flexibility to accommodate and process number of products.
2. Very high investment for setting flow lines.
3. Very limited product differentiation.

2.2 Productivity

Productivity is the relation between what is produced to what is used to produce it. It can be expressed as:

$$Productivity = \frac{Output}{Input} \quad (1)$$

Productivity shows how efficient the production system is and indicates how well factors of production (land, capital, labour and energy) are utilised. (Kumar, 2008, p. 172.)

2.3 Factors influencing productivity

Factors influencing productivity can be classified broadly into two categories: controllable (or internal) factors and un-controllable (or external) factors.

2.3.1 Controllable (or internal) factors

Product factor: To what extent does the product meets output requirements and to judge the produce by its usefulness.

Plant and equipment: Reduction of idle time and less down times due to proper maintenance increase productivity. Other than that it is a good advice to pay attention to utilisation, age, cost and investments.

Technology: Innovation and latest technologies can improve productivity to a great extent.
The various aspects of technology factors to
be considered are:

1. Size and capacity of the plant.
2. Timely supply and quality of inputs.
3. Production planning and control.
4. Repairs and maintenance.
5. Waste reduction.
6. Efficient material handling system

Material and energy: Reducing materials and energy waste considerably improves productivity.

1. Selection of quality material and right material for the job.
2. Control of wastage and scrap.
3. Effective stock control.
4. Development of sources of supply.
5. Optimum energy utilisation and energy savings.

Human factors: Productivity is basically dependent upon human competence and skill. There are several factors that influence ability to work effectively such as education, training, experience etc., of the employees. Motivation of employees plays a big role in productivity.

Work methods: Productivity can be increased by improving methods that are used at work and changing the way the work is done.(Kumar, 2008, p. 173.)

2.3.2 Uncontrollable (or external) factors

Structural adjustments: Structural adjustments include both economic and social changes.

Some of **economical** changes include shift in employment from one industry to another, import of technology and competitiveness on the market.

Natural resources: Manpower, land and raw materials that are important to increase productivity

Government and infrastructure: Government taxes on business and industry, policies regarding trade, transportation and communications. (Kumar, 2008, p. 174.)

3 CURRENT SITUATION

A few years ago the company made a few bad investments which led to a bad economical situation that forced it to make some drastic changes including cutting salaries and selling some assets to remain in the market. That led to a decrease in production from 7000 cylinders a month to 4500.

About a year ago the company acquired a valuable customer that now orders 80-85% of total products. That customer specializes in agricultural machines and equipment so in summer period the demand for cylinders will increase. Since this year was quite profitable for the company and now there is extra money, it is time to make right investments to return to previous production capacities before end of summer.

3.1 Organization at Belautozapchast

Belautozapchast has full cycle manufacturing of hydraulic cylinders which consists of tube and rod cutting, machining, welding, painting, assembling and testing.

3.1.1 Blank section

Four automatic medium sized saws are used to cut the tube and rod blanks into correct sizes. There are two other saws used for major blanks (80mm+). Two teams are working here from Monday to Friday, the morning shift works from 7am to 4pm, while the night shift works from 4pm to 1am. Shifts are swapped every week.

3.1.2 CNC section

Eight medium sized CNC lathe machines are laid in pairs so that one operator would be working on two machines. There is one big sized CNC lathe machine for shells 80mm+ in diameter. On top of that there are two big CNC milling machines.

Four teams, consisting of one taskmaster and 4-6 operators, are working 12 hours shifts every day except holidays. Teams are unbalanced which leads to some days having several people working on one machine and others having one operator working on three machines. Shifts are organized in a way that one teams works a day in morning shift, next day is nights shift and then two off-days.

During morning shifts there are 2 people operating single CNC lathe and CNC milling machine. Eight CNC machines are paired in a way so that one machine requires manual handling while the other one is semiautomatic with a feeder and a catcher.

3.1.3 Welding

The company has four welders working 8-hours shifts from Monday to Friday. There is nothing much to say about these except that during summer holidays or sick leaves welders can be asked to work a few extra hours to fill in the quota.

3.1.4 Painting

Near the storage there is a chemical department for the coating hydraulic parts with protection and paint. This process is semi automatic and requires only loading the parts on hooks while the rest is done by the machine. One team works in 8 hour shifts from Monday to Friday.

3.1.5 Assembly and testing

Near the storage and painting area hydraulic cylinders are assembled by two teams working in a similar mode as the blank section team, except for the fact that in case of increased lead times due to bad production or material planning they get to rest more often, when there is nothing to assemble. This happened often mostly due to delays of outsourced components. Right after assembly, the hydraulic cylinder undergoes a pressure test and is then stored.

3.2 **Current state of affairs**

Belautozapchast uses a batch production system, not the textbook one but the one more attached to real life. For their main client they have a contract to ship 2000-5000 cylinders a month depending on the season. The problem is that there are 30 different cylinders in their catalogue for that client ranging from 160mm to 800mm in length and from 32mm to 125mm in diameter. On top of that they have extra clients to take care with unique cylinders that first need to be designer by engineers and quite often can provide a challenge to manufacture. To make matters worse, their main client often calls them to tell which cylinders they need in a hurry in a few days, and because of that they often have to stop one batch midway to start another one, which is more valued at the moment. Because of such a rush, long term planning is diffucult and lead times are too high.

4 ANALYSIS

After several weeks at work and after discussions with workers, the main bottleneck in production line was determined to be the CNC segment. While other parts of the line were not always utilized to full capacity, the CNC segment was the one falling behind the most in production planning. Therefore it became also the starting point of this project.

4.1 Production capacity

After gathering enough data on lead times, together with the Chief Engineer an analysis on the total production capacity was done and can be seen in Table 1.This calculation is still an estimation due to the fact that some machines are specialized to one part and in some cases a less efficient machine is used for work there may also be some drawbacks in the form of maintenance and holidays.

In April 2017 the company was asked to deliver 5091 cylinders, but out of them only 3057 were manufactured and sent on time. Eleven of these cylinders were ordered all the time in medium to high quantities, having difference from each other and with a lead time calculated separately while 19 other cylinders were ordered in small batches from 10 to 50 cylinders, similar to each other and with a common lead time.

Cylinders consist from 5 to 7 different parts, each with their own machining time. In the table time per unit has all parts machining time summed up, while total time represents time for the whole order. Summing everything up and converting in days we get a number of 211.52 days to manufacture 5096 cylinders on one machine. But since we have nine machines, we have to divide it by that number plus multiply by safety factor of 1.2 to compensate for any delays, waiting time or loss of efficiency due to less compatible machine.

Final number is 28 days which roughly equals a full month. This leads to the conclusion that total production capacity of the CNC section is about 5000 hydraulic cylinders per month. A question arises why only 3057 cylinders were manufactured in April (Maynard, 2007).

Table 1. Production capacity calculation.

Cylinder	Ammount	Time per unit	Total Minutes	Days
BHC 80.63.800-1	500	97,41	48705,00	43,88
BHC 40.20.160	1200	40,67	48804,00	43,97
BHC 63.32.200M27	600	55,82	33492,00	30,17
BHC 40.20.160-02	400	32,91	13164,00	11,86
BHC 01.32.20.260	500	31,29	15645,00	14,09
BHC 01.35.25.250	250	38,30	9575,00	8,63
BHC 01.32.25.250-1	230	31,87	7330,10	6,60
BHC 32.25.250-1	300	32,28	9684,00	8,72
BHC 40.20.200-12	20	36,30	726,00	0,65
BHC 32.20.115-1	90	29,53	2657,70	2,39
BHC 63.32.500	300	49,02	14706,00	13,25
Other	701	43,22	30295,95	27,29
	5091		**Total**	211,52
			Days	28,20

4.2 Productivity of workers

One of the reasons of low production is low productivity of workers. Working time is standardized and every day it is noted how many components each workers has given to the storage. The number of parts is compared to the set numbers and individual workers efficiency is evaluated.

Table 2. Workers efficiency

		Efficiency			
Operator		**April**	**March**	**February**	**January**
Worker 1		0,96	1,02	1,00	0,99
		0,93	0,72	0,70	1,13
Worker 2		0,97	1,03	0,94	1,00
		0,50	0,60	0,31	0,61
Team 1	**Average**	0,84			
Worker 3		0,98	1,01	0,99	1,01
		0,84	1,00	0,57	1,01
Worker 4		0,67	0,88	0,91	1,00
		0,44			0,32
Worker 5		1,00	1,04	1,03	1,02
		0,63	0,31	0,14	0,59
Worker 6		0,91	0,98	0,93	0,97
		0,81	0,40	0,87	0,93
Team 2	**Average**	0,79			
Worker 7		0,98	1,04	1,03	1,02
		0,89	0,92	0,78	0,92
Worker 8		0,93	0,82	0,95	0,95
		0,6		0,56	0,43
Worker 9		1	1,05	0,97	1,03
		0,98	1,1	0,71	0,95
Worker 10		0,996	0,94	0,9	0,97
		0,76			0,71
Worker 11		1	0,98	0,95	1,02
		0	0,45	0,72	0,97
Team 3	**Average**	0,8136			
Worker 12		0,94	1	0,99	0,96
		0,56	0,53	0,76	0,69
Worker 13		0,97	0,96	0,95	1
		0,34	0,13	0,61	
Worker 14		0,97	0,96	0,94	0,91
		0,57	0,73	0,67	0,58
Worker 15		0,92	0,96	0,91	0,99
		0,44			
Worker 16		1	1	1	1
		0			
Team 4	**Average**	0,671			

Total Average	77,74%	83,25%	81,59%	84,59%
Average on main	94,98%			
Average on second	58,06%			

Table 2 shows evaluation of workers efficiency over four month period. The data from April was more thoroughly observed as we needed it for our case study but other months were also added to see any patterns there. First line shows workers efficiency on the main machine while the line under shows how well she/he was doing on the second one. Some workers do not work the second machine due too many people in the team or lacking experience to properly work on both machines at the same time.

There were only two workers in the first team because three others came from the maintenance segments and were evaluated differently. Both workers have been in the company for several years but worker 1 is a diligent worker who does the job even though the payment of the second machine was reduced, while the worker 2 lack much desire to do proper work on both machines.

Second team has a mix of both good and bad workers. Here there a people who even do bad work on their main machine even thought that leads to a big deduction in their salary. Except worker 3 and 6, others do not have a desire to work on second machine for extra money, so they either do a bad job or do not work at all there.

Third team has mostly good workers that try always coming earlier and doing a proper work on both machines. But because there are five people on the team sometimes there are not enough free machines for everyone, as during daytime there are other workers as well and single machine are available only during night shifts.

Last team is made out of new and inexperienced workers. Worker 15 has been working for less than half a year and still cannot properly work on both machines at a time. And worker 16 is hired under special contract to work only on one machine and help new workers and since his productivity is not evaluated he always has 100% efficiency.

Workers productivity is evaluated at the end of their shifts where they present the amount of parts they machined during their work and controllers compare these numbers to standard times they have and calculate how productive they were.

From table 2 it can be seen that the total efficiency including both machines was 80% on average per worker. The main machine efficiency is around 95% mostly due to a contract that obliges workers to have over 90% efficiency there. But the second machine is optional and is paid less than the first one. Therefore many workers had no reasons or motivation to make an effort on the second machine since it is not mandatory and did not pay well.

4.3 Set-up times

A lot of time is wasted on the set-up even thought order for one type of cylinder can be 1000 pieces, the client will only need a quarter of that and a bit of everything else, because otherwise they would not be able to make their machine. Therefore batches of 50-100 parts are made and then the machine is set to do another part and that takes time and reduces some efficiency. So even if workers had all the motivation in the world they will not be able to work 100% all the time due to set-up time.

Company have been working with their current main client for quite some time now and as of now every machine has programs stored in their memory for those products. But sometimes a unique hydraulic cylinder has to be manufactured and for that a new program is done.

In every team there is a taskmaster who does all adjustments on CNC machines. Most of the time that works out well but sometimes 2 or even 3 machines can go out of work due to some error or end of batch. In that case while taskmaster is adjusting one machine, all other non-working machines are going to wait and lose even more productivity. Luckily that happens rarely.

Nevertheless, quite often a lot of time is wasted to find the right clamp or jaws for a new part. Sometimes there are no rare tools available and taskmaster has to take the insert from another machine where it is not in use at the moment.

In April a work sampling was conducted to learn more on the how set-up time affected production. Table 3 shows precisely how much time is lost due to that. On average 5 adjustments are done per shift that lead to 7 hours of lost time. In a month that equals to 370 wasted hours, this is 6% of the total working time.

Table 3. Set-up times

Date	Quantity	Time (h)
01.04.2017	5	7
	3	5
02.04.2017	5	7
	2	4
03.04.2017	8	10
	9	10
04.04.2017	4	7
	2	2
05.04.2017	2	5
	7	11
06.04.2017	6	6
	5	8
07.04.2017	2	3
	4	3,5
08.04.2017	3	7
	3	5
09.04.2017	3	5
	2	4
10.04.2017	5	6
	2	3,5
11.04.2017	3	5
	3	4,50
12.04.2017	2	3
	3	3
13.04.2017	4	8
	4	9
14.04.2017	3	4
	7	8
15.04.2017	7	7
17.04.2017	14	15
	9	12,5
18.04.2017	8	9
	3	4,5
19.04.2017	6	8,5
	9	10
20.04.2017	4	7,5
	7	9

21.04.2017	7	11
	4	6
22.04.2017	6	6
	7	11
23.04.2017	6	8
	7	7
24.04.2017	5	8
25.04.2017		
26.04.2017	7	8
	5	6
27.04.2017	6	6
	7	8
28.04.2017	7	10
	4	5,5
29.04.2017	7	11
	6	9
30.04.2017	3	4,5
Total	272	371,5
Average	5,13	7,01

5 SOLUTION

After an analysis we could determine the main reasons causing the CNC segment to fall behind. In this chapter the solutions are discussed as to addressing the problems and to increase productivity.

5.1 Motivation and incentive

5.1.1 Action

Quite a major loss in productivity was due to the low motivation of the workers to work harder. A few worked hard but they could not cover for the others. During bad times when the company was struggling there were cuts in salaries which still remained. That was the main problem we faced with the workers.

A decision was made to rally operators for a discussion to hear all their complaints and address them. Not surprisingly, main complaint was the payment for the second machine. Everyone except one worker vouched to start working better if salary was to increase.

Better salary always leads to better motivation at work but it was decided to change a bit workers proposal and add an incentive to them: the better their productivity is, the better their salary coefficient is going to become. This supposedly should negate a situation where salary was increased but the productivity remained the same and company just lost money.

Another complaint was that during set-up the machine is idling and worker productivity is lowering. So that even if he wants to work, he cannot due to how long it sometimes takes to set-up a machine.

5.1.2 Result

Increasing salary led to a drastic increase in production in May, especially closer to the end when other methods started to show results as well. From average of 80%, workers efficiency increased to 88%. It might be just a short burst of increased efficiency until workers will want to relax again but incentive was made for such case, so that they would have more motivation to work better and not slack.

5.2 **Out of box adjustments**

5.2.1 Action

There is no way to eliminate adjustments, they will always be there, but it is possible to decrease the time they take by preparing in advance.

Writing programs usually not requires too much time usually but since a cylinder has 7 different parts that need to be programmed, it can stack and increase time dramatically. A person was put in charge checking the production plan and preparing all the programs on computer and uploading them on a memory card for quick usage when neede.

This required some preparations to create a base of current programs on the computer, so that coordinates and tools can always be correct when writing a program for one machine out of nine.

On top of that, the person in charge was also given a task to make sure that right tools and jaws for the next batch will always be ready and waiting so that operators would not need to waste time searching while machine is idling.

5.2.2 Result

It took us some time at first to adopt the strategy and several national holidays pushed us back a little but we implemented the solution of having another person to be in charge of preparing programs and tools in advance. The results are more visibly seen after 15th of May, after the strategy was fully implemented.

By the end of the month amount of hours wasted on set-up was equal to 258. If we compare it to the previous month:

$$371.5 - 258 = 113.5\ (h)$$

$$^{113.5}/_{371.5} = 30\%$$

We have saved about 113 hours compared to April which converts to about 30% decreased set-up time.

In May we had increased amount of short-set up in the beginning of the month because there were holidays as well as workers started working faster that led to some short maintenance breaks.

Table 5. Set-up times in May

Date	Quantity	Time (h)
01.05.2017		
02.05.2017		
03.05.2017	19	16
04.05.2017	15	13
05.05.2017	16	15
06.05.2017	12	10
07.05.2017		
08.05.2017		
09.05.2017	15	15
10.05.2017	17	17
11.05.2017	16	13
12.05.2017	14	12
13.05.2017	11	11
14.05.2017	13	9
15.05.2017	14	10
16.05.2017	11	9
17.05.2017	9	6,5
18.05.2017	14	5,5
19.05.2017	12	5
20.05.2017	8	6,5
21.05.2017	11	8
22.05.2017	13	10
23.05.2017	8	7
24.05.2017	9	8
25.05.2017	11	8
26.05.2017	12	9
27.05.2017	15	10
28.05.2017	13	8
29.05.2017	10	7
30.05.2017	13	6,5
31.05.2017	9	3,5
Total	340	258
Average	12,59	9,56

5.3 Machining parameters

Due to having a limited budget on production, machining parameters were set to a minimum to save as much money as possible. Both the cutting speed and feed was reduced to allow insert to work as long as possible and reduce the chance of machine breaking because of work. The fewer products are made the less frequent is machine maintenance.

Rule of thumb says that if you increase cutting speed by 20% then tool life decreases up to 50%. And if you increase cutting speed by 50% then tool life goes down by up to 80% (Clarke, 2005).

It is possible to increase production speed by using more inserts. If we sum up amount of cylinders manufactured in the past 3 months - that would be 11847. And then divide that by money spent on inserts in that period, which is 39830 euro.

$$\frac{11847}{39830} = 3.3\ euro$$

But this is only in theory and needs testing, which I have not done yet.

6 CONCLUSION

The objective of this research project was to increase the production volumes at Belautozapchast. Two solutions were implemented during this work which resulted to an 18% increase in volume the produced, compared to methods used a month earlier. It is possible to increase these numbers even further especially if the cutting speed is to be increased, which can go up to 40% of anincrease in productivity. That would of course lead to performing the standardization all over again, since increased machine parameters will change the current standards set by operators.

The focus of my work was the CNC segment due to it being a bottleneck in the production line but after dealing with it there are still things to do and work methods to be improved. For example machining parameters and tool life, there is a possibility to find an optimal relation between how fast machining is done and how long the tool will last. At the moment they spend about 3 euro in tool costs to produce one cylinder that is not much and can safely be increased to 5 euro. In theory that should allow us to increase speed by 20-30%. But that is only theory and needs to be tested, which is my goal for the rest of the summer here.

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